# CLAIMS

We claim:

1. A system for mapping a surface of a three-dimensional object, comprising:

a projecting optical system adapted to project light onto an object;

a pre-correction system adapted to compensate a light beam to be projected onto the object for at least one aberration in the object, the pre-correction system being positioned in between the projecting optical system and the object;

an imaging system adapted to collect light scattered by the object; and

a wavefront sensor adapted to receive the light collected by the imaging system and to sense a wavefront of the received light.

2. The system of claim 1, further comprising:

means for adjusting the compensation applied to the light beam by the pre-correction system to thereby change the wavefront of the light received by the wavefront sensor; and

means for stitching together the sensed wavefronts of the light received by the wavefront sensor for each compensation to map the surface of the object.

3. The system of claim 1, wherein the wavefront sensor is a Shack-Hartmann wavefront sensor.

4. The system of claim 1, further comprising a dynamic-range-limiting aperture adapted to insure that the wavefront sensor only sees light within a dynamic range of the

system.

5. The system of claim 1, wherein the pre-correction system includes at least one variable focal length lens.

6. The system for measuring errors of claim 5, wherein the pre-correction system includes a processor controlling the variable focal length lens.

7. The system of claim 1, wherein the pre-correction system comprises a telescope having two lenses, at least one of said lenses being movable.

8. The system of claim 7, further comprising a processor adapted to move said movable lens to a plurality of positions and to stitch together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

9. The system of claim 7, further comprising further comprising a dynamic-range-limiting aperture disposed in an optical path between the two lenses and being adapted to insure that the wavefront sensor only sees light within a dynamic range of the system.

10. The system of claim 9, further comprising a processor adapted to move said movable lens to a plurality of positions and to stitch together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

11. A method of mapping an object, comprising:

(a) projecting a light beam onto an object;

(b) compensating the light beam to be projected onto the object for at least one aberration in the object;

(c) collecting light scattered by the object and providing the collected light to a wavefront sensor; and

(d) sensing at the wavefront sensor a wavefront of the collected light scattered by the object.

12. The method of claim 11, further comprising:

(e) changing a compensation applied to the light beam;

(f) repeating steps (b) through (e) to obtain N sensed wavefronts; and

(f) stitching together the N sensed wavefronts to map the object.

13. The method of claim 11, further comprising passing the light scattered from the object through a dynamic-range-limiting aperture adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

14. The method of claim 11, wherein compensating the light beam comprises passing the light beam through a telescope having two lenses, at least one of said lenses being movable.

15. The method of claim 14, further comprising:

(e) moving said movable lens to a plurality of positions; and

(f) stitching together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

16. The method of claim 14, further comprising further comprising further comprising passing the light scattered from the object through a dynamic-range-limiting aperture disposed in an optical path between the two lenses adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

17. The method of claim 16, further comprising :

(e) moving said movable lens to a plurality of positions; and

(f) stitching together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

18. A system for measuring an optical characteristic of an optically transmissive object, comprising:

a projecting optical system which projects light through an optically transmissive object;

a correction system adapted to at least partially compensate a light beam that has been projected through the object for at least one optical property of the object;

an imaging system adapted to collect the light that has been projected through the object; and

a wavefront sensor adapted to receive the light collected by the imaging system and to sense a wavefront of the received light.

19. The system of claim 18, wherein the object is a lens and the optical property that the correction system compensates for is a focal power of the lens.

20. The system of claim 18, further comprising means for adjusting the compensation applied to the light beam by the correction system.

21. The system of claim 18, wherein the wavefront sensor is a Shack-Hartmann wavefront sensor.

22. The system of claim 18, further comprising a dynamic-range-limiting aperture adapted to insure that the wavefront sensor only sees light within a dynamic range of the system.

23. The system of claim 18, wherein the correction system includes at least one variable focal length lens.

24. The system for measuring errors of claim 23, wherein the correction system

includes a processor controlling the variable focal length lens.

25. The system of claim 18, wherein the correction system comprises a telescope having two lenses, at least one of said lenses being movable.

26. The system of claim 25, further comprising a processor adapted to move said movable lens to a plurality of positions and to stitch together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

27. The system of claim 25, further comprising further comprising a dynamic-range-limiting aperture disposed in an optical path between the two lenses and being adapted to insure that the wavefront sensor only sees light within a dynamic range of the system.

28. The system of claim 27, further comprising a processor adapted to move said movable lens to a plurality of positions and to stitch together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

29. A method of measuring an optical quality of an optically transmissive object, comprising:

(a) projecting a light beam through an optically transmissive object;

(b) at least partially compensating the light beam that has been projected through the object for at least one optical property of the object;

(c) collecting the light beam that has been projected through the object and providing the collected light to a wavefront sensor; and

(d) sensing at the wavefront sensor a wavefront of the collected light.

30. The method of claim 29, wherein the object is a lens and wherein at least partially compensating the light beam that has been projected through the object for at least one optical property of the object includes compensating for a focal power of the lens.

31. The method of claim 30, where the method measures the focal power of the lens.

32. The method of claim 29, further comprising:

(e) changing a compensation applied to the light beam;

(f) repeating steps (b) through (e) to obtain N sensed wavefronts; and

(f) stitching together the N sensed wavefronts to map the object.

33. The method of claim 29, further comprising passing through a dynamic-range-limiting aperture the light beam that has been projected through the object, the dynamic-range-limiting aperture being adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

34. The method of claim 29, wherein compensating the light beam comprises passing the light beam through a telescope having two lenses, at least one of said lenses being

movable.

35. The method of claim 34, further comprising:

(e) moving said movable lens to a plurality of positions; and

(f) stitching together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

36. The method of claim 34, further comprising further comprising further comprising passing through a dynamic-range-limiting aperture the light beam that has been projected through the object, the dynamic-range-limiting aperture being disposed in an optical path between the two lenses and being adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

37. The method of claim 36, further comprising :

(e) moving said movable lens to a plurality of positions; and

(f) stitching together the sensed wavefronts of the light received by the wavefront sensor at each of the positions.

38. A method of mapping a surface of an object, comprising:

(a) projecting a light beam onto a surface of an object;

(b) collecting light scattered by a first portion of the surface of the object and rejecting light scattered by a second portion of the surface of the object;

(c) sensing at a wavefront sensor a wavefront of the collected light returned by the portion of the surface of the object;

(d) repeating steps (a) through (c) for a plurality of different portions of the surface of the object that together span a target area of the surface of the object; and

(e) stitching together the sensed wavefronts to produce a complete measurement of the target area of the surface of the object.

39. The method of claim 38, wherein collecting light scattered by a first portion of the surface of the object and rejecting light scattered by a second portion of the surface of the object comprises passing the light scattered by the first and second portions through a dynamic-range-limiting aperture adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

40. The method of claim 38, wherein collecting light scattered by a first portion of the surface of the object comprises passing through a telescope having two lenses the light scattered by a first portion of the surface of the object, at least one of said lenses being movable, and wherein repeating steps (a) through (c) for a plurality of different portions of the surface of the object comprises moving the movable lens to a plurality of different positions.

41. The method of claim 40, wherein collecting light scattered by a first portion of the surface of the object and rejecting light scattered by a second portion of the surface of the

object comprises passing the light scattered by the first and second portions through a dynamic-range-limiting aperture disposed in an optical path between the first and second lenses, the dynamic-range-limiting aperture being adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

42. A method of measuring an optically transmissive object, comprising:

(a) projecting a light beam through at least a portion of an object;

(b) collecting light passed through the portion of the object;

(c) sensing at a wavefront sensor a wavefront of the collected light passed through the portion of the object;

(d) repeating steps (a) through (c) for a plurality of different portions of the object that together span a target area of the object; and

(e) stitching together the sensed wavefronts to produce a complete measurement of the target area of the object.

43. The method of claim 42, further comprising passing through a dynamic-range-limiting aperture the light passed through the portion of the object, the a dynamic-range-limiting aperture being adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

44. The method of claim 42, wherein collecting light passed through the portion of the object comprises passing through a telescope having two lenses the light passed through

the portion of the object, at least one of said lenses being movable, and wherein repeating steps (a) through (c) for a plurality of different portions of the surface of the object comprises moving the movable lens to a plurality of different positions.

45. The method of claim 44, further comprising passing through a dynamic-range-limiting aperture the light passed through the portion of the object, the a dynamic-range-limiting aperture being adapted to insure that the wavefront sensor only sees light within a dynamic range of the wavefront sensor.

46. A method of mapping a surface of an object, comprising:

(a) locating a light source a first distance from an object;

(b) projecting a light beam from the light source onto a surface of the object;

(c) collecting light scattered by the surface of the object;

(d) sensing at a wavefront sensor a wavefront comprising a difference between a wavefront of the collected light and a reference wavefront;

(e) changing the distance between the light source and the object;

(f) repeating steps (b) through (e) to produce N sensed wavefronts; and

(g) stitching together the N sensed wavefronts to produce a complete measurement of the target area of the surface of the object.

47. A method of measuring an optically transmissive object, comprising:

(a) locating a light source a first distance from an optically transmissive object;

(b) projecting a light beam from the light source through the object;

(c) collecting light projected through the object;

(d) sensing a wavefront comprising a difference between a wavefront of the collected light and a reference wavefront;

(e) changing the distance between the light source and the object;

(f) repeating steps (b) through (e) to produce N sensed wavefronts; and

(g) stitching together the N sensed wavefronts to produce a complete measurement of the target area of the surface of the object.

48. A point light source for producing a spherical wave, comprising:

a light source;

a diffuser adapted to receive light from the light source; and

a structure having an aperture adapted to receive and pass therethrough the light from the diffuser.

49. The point light source of claim 48, further comprising a tapered fiber adapted to receive the light from the light emitting diode and to provide the light to the diffuser.

50. The point light source of claim 48, further comprising a tapered fiber bundle adapted to receive the light from the light emitting diode and to provide the light to the diffuser.

51. A method of determining when a portion of a light wavefront received by a wavefront sensor exceeds the dynamic range of the wavefront sensor, the method comprising:

assigning a group of N pixels of a wavefront sensor to a focal spot;

providing a first light wavefront to the wavefront sensor under conditions known to be within a dynamic range of the wavefront sensor;

calculating a reference value, $\sigma_k^{REF}$, for a second moment of the focal spot produced by the first light wavefront within the group of N pixels;

providing a second light wavefront to the wavefront sensor;

calculating a value of the $\sigma_k$, for a second moment of the focal spot produced by the second light wavefront within the group of N pixels; and

determining that the second light wavefront is within the dynamic range of the wavefront sensor within the group of N pixels when $\left|\sigma_k - \sigma_k^{REF}\right| < t_\sigma$, where $t_\sigma$ is a set threshold value.

52. The method of claim 51, where $t_\sigma$ is set to be at least twice an average of reference second moment values of a plurality of groups of N pixels spanning the wavefront sensor.

53. A method of mapping a surface of an object, comprising:

projecting a light beam onto an object;

compensating the light beam to be projected onto the object for aberrations in the object;

passing light scattered by the object through a dynamic-range-limiting aperture;

collecting light passed through the dynamic-range-limiting aperture and providing the collected light to a wavefront sensor; and

sensing a wavefront of the collected light.

54. The method of claim 53, wherein the wavefront of the collected light is sensed with a Shack-Hartmann wavefront sensor having a first plurality of lenslets for receiving and focusing the wavefront into focal spots, and a second plurality of pixels adapted to receive the focal spots, and wherein the dynamic-range-limiting aperture has a same shape as a shape of one of the lenslets.

55. The method of claim 53, where the dynamic-range-limiting aperture has a rectangular shape.

56. A method of determining a position of a focal spot on a wavefront sensor, comprising:

assigning a first group of N pixels of a wavefront sensor to a focal spot;

providing a light wavefront to the wavefront sensor;

measuring an irradiance distribution of the light wavefront across the N pixels of the first group;

calculating a preliminary centroid position of the focal spot as a first moment of the irradiance distribution of the light wavefront across the N pixels of the first group;

assigning a second group of N pixels of the wavefront sensor to the focal spot, where the second group of N pixels is approximately centered at the preliminary centroid position; and

calculating a location of the focal spot as a first moment of the power of irradiance distribution of the light wavefront across the N pixels of the second group.

57. A method of determining a wavefront of light received by a wavefront sensor, the method comprising:

(a) providing a light wavefront to a wavefront sensor;

(b) assigning pixels of the wavefront sensor to a first plurality of areas-of-interest (AOIs);

(c) determining a first region of the wavefront sensor where the received light wavefront is within a dynamic range of the wavefront sensor for all AOIs within the first region;

(d) calculating locations for centers of light spots of received light for all AOIs within the first region;

(e) calculated a fitted wavefront for the received light wavefront over the first region;

(f) computing a slope of the fitted wavefront at each AOI within the first region;

(g) projecting locations for centers of light spots of received light for a second region of the wavefront sensor larger than the first region, using the slopes of the fitted wavefront within the first region;

(h) reassigning the pixels of the wavefront sensor to a second plurality of areas-of-

interest (AOIs) each centered on one of the calculated or projected centers of light spots;

(i) determining a new first region of the wavefront sensor where the received light wavefront is within a dynamic range of the wavefront sensor for all AOIs; and

(j) repeating steps (d) through (i) until one of: (i) the new first region is no larger than a previous first region; and (ii) the new first region spans substantially the entire wavefront sensor.

58. A method of measuring a focal length (F) of a lens, comprising:

(a) locating a light source on a first side of a lens, one of the light source and the lens being located at a position $Z_i$;

(b) locating a wavefront sensor a fixed distance (L) from the lens on a second side thereof;

(c) projecting a light beam from the light source through the lens;

(d) collecting light passed through lens;

(e) sensing a wavefront of the collected light at the wavefront sensor;

(f) measuring a corresponding vergence $P_i$ of the light;

(g) incrementing i by 1, and moving the position of one of the light source and the lens to a new position $Z_i$;

(h) repeating steps (c) through (g) to obtain N values of $Z_i$ and $P_i$; and

(i) applying the N values of $Z_i$ and $P_i$ to a least squares fit algorithm to solve for the focal length (F).

59. The method of claim PP, wherein the light source is moved to the position $Z_i$, and wherein the N values of $Z_i$ and $P_i$ are applied to a least squares fit algorithm to solve for the focal length F, using the equation $P_i = (Z_i - Z_o)/(f^2 = (f - L)(Z_i - Z_o))$, where $Z_o$ is the position of the light source where the collected light at the wavefront sensor is collimated.